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Report No. AAEE/Tech/236/Nav.



MINISTRY OF AVIATION

**AEROPLANE AND ARMAMENT
EXPERIMENTAL ESTABLISHMENT**

BOSCOMBE DOWN

Report No. AAEE/Tech/236/Nav.

CATALOGED BY DDC

AS AD No. 346022L

THE ALIGNMENT OF EQUIPMENT AND PROJECTILES ON AIRCRAFT

PRESENTED BY

SQDN. LDR. P. H. R. CLIFFORD AND FLT. LT. I. K. BARTLEY

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Report No. AAEE/Tech/236/Nav.

AEROPLANE AND ARMAMENT EXPERIMENTAL ESTABLISHMENT
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5 4 OCT 1963

The Alignment of Equipment and Projectiles on Aircraft

Presented by

Sqdn. Ldr. P. H. R. Clifford and Flt. Lt. T. K. Bartley

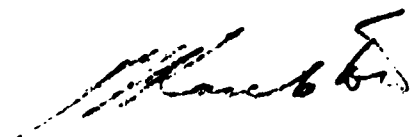
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Summary

This document describes the need for alignment of equipment and projectiles on aircraft, discusses the accuracy to which equipments require aligning and methods of achieving the necessary accuracy. It also emphasises the importance of developing an alignment plan for an aircraft or weapon system, as a whole, at the design stage.

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1. Introduction

Much attention has previously been given to the need for aligning navigational systems in the horizontal and the vertical planes. The alignment problem has, in the main, been that of aligning inertial navigators or gyro platforms, but the problem also affects navigation and attack equipment, and projectiles.

In the past insufficient consideration has been given to the alignment of navigational sub-systems (including missile guidance systems) to the aircraft on which they are carried. The Experimental Navigation Division of the Aeroplane and Armament Experimental Establishment is investigating current methods of aligning equipments to aircraft with a view to improving them and recommending a future policy for the overall alignment of navigation and weapon systems, for service and civil aircraft.

The aim of this document is to explain the need for alignment to a common datum, to discuss the accuracy to which equipments and projectiles need aligning and methods of achieving this. These topics are considered in relation to three possible applications: a land based military aircraft, a sea based military aircraft and a land based civil or military route transport aircraft. A subsidiary aim is to emphasise the importance of deciding, at the onset, on an alignment plan for the aircraft or weapon system as a whole, rather than the current piecemeal approach whereby each element of the navigation system relies on its own method of alignment.

2. The Need for Alignment to a Common Datum

It is almost axiomatic that navigational equipments on an aircraft should all make their measurements with respect to the same datum direction, yet this basic principle often seems to be forgotten.

2.1 Alignment of Equipments on Military Aircraft

For all military aircraft used in an offensive capacity a certain accuracy radius from the target is required. The Mean Area of Effectiveness of any weapon (conventional or nuclear) to be employed will clearly have a direct relationship on the Circular Error Probable (C.E.P.) required of the navigation or attack system. Transport aircraft used in a support role will have similarly tight requirements in order that supplies and troops are dropped within a hundred feet or so of the aiming point in a dropping zone. The accuracy requirements for aircraft used to deliver conventional weapons, or support ground forces in limited wars, are just as stringent as those for strategic bomber aircraft. Alignment requirements of 0.1° are frequently required for current navigation equipments.

It will be apparent that if either doppler or astro is used to crutch an inertial platform, output data must be related to an axis common with the platform; frequently this axis is the heading of the vehicle. Similarly if position information concerning the vehicle itself, or a target, is required to be transferred from a radar equipment to a computer the scanner and aircraft datum must be aligned.

The above arguments will obviously apply to any military aircraft regardless of whether they are based on airfields or aircraft carriers.

2.2 Alignment of Equipments on Civil Aircraft

The navigation accuracy required of civil or military route transport aircraft is related to two demands, those of operating economy and air traffic control regulations. If these aircraft are required to know position only to about 5 nautical miles, the alignment of navigation

equipments is less important at present than on military offensive aircraft.

As an example an alignment bias of 1° on a doppler (or compass) in a Comet 4C would only incur the consumption of an extra 800 lb. of fuel if a terminal error of 44 miles over its operating range could be accepted. If however an aircraft is required to stay within 5 nautical miles of track and it is assumed that position is fixed once every half an hour, then an alignment accuracy of between $\frac{1}{2}^{\circ}$ and 1° would be necessary. Even this is a less stringent alignment tolerance than that currently accepted on military aircraft.

3. Determination of Alignment Accuracy Required

The methods currently used by Experimental Navigation Division, A. & A.E.F., to determine the alignment requirements for equipments and/or associated projectiles are quite unrevolutionary. An error budget is compiled for the weapon system under consideration which takes account of:-

- (a) The accuracy required from the overall system.
- (b) The accuracy desired or available from each equipment within the system.
- (c) The accuracy of transmitting the required data (i.e. probable errors in synchros, gearing etc.). Consideration is also given to weak links in the transmission chain that could introduce disproportionately large errors and which may, or may not, be capable of improvement.

Analysis of the above factors indicates the accuracy with which elements of the system should be aligned to meet current and possible future requirements. The alignment accuracy to be specified (in order that alignment errors do not have a significant effect upon accuracy) should be $\frac{1}{2}$ of the angular accuracy required. For example if an astro tracker or doppler is required to be accurate to 1° it should be aligned $\frac{1}{2}^{\circ}$. This is based on the fact that the root sum square (r.s.s.) of 1 and $\frac{1}{2}$ is close to 1. For this method to be acceptable, however, all alignment errors must be random in nature; bias errors should be added in arithmetically rather than by r.s.s. methods.

Illustrations are given below of the order of result obtained when this procedure is used to derive alignment requirements.

3.1 Alignment Accuracy Requirements for a Strategic Bomber/Missile Carrier

A bomber intended to launch an air to surface missile would normally use the following equipments:-

- (a) A search radar for fixing.
- (b) A compass or heading reference system.
- (c) A doppler radar.

The weapon system designer would be expected to quote the accuracy required of each sub-system. For example these might be of the order of 1,500 ft. acceptable circular radar fixing error, 0.3° heading error and 0.2° permissible doppler error. The alignment accuracy required for each of these equipments (in order that the misalignment between the missile and its information sources was not a significant factor) would be of the order of:-

- (a) Radar scanner $\frac{1}{2}^{\circ}$.
- (b) Heading reference 0.1° .
- (c) Doppler aerial slightly less than 0.1° .

3.2 Alignment Accuracy Requirements for a Tactical Strike Aircraft

For a tactical strike aircraft (e.g. Canberra, Buccaneer) required to obtain a hypothetical C.D.P. of, say, 1,500 ft. The equipments which might be involved and their associated alignment tolerances could be:-

- (a) A search radar ($\frac{1}{4}^{\circ}$ in each axis)
- (b) Gyro platform ($\frac{1}{2}^{\circ}$ in each axis)
- (c) Visual attack sight (0.8° in each axis).

3.3 Vertical Alignment in Military Aircraft

In the past there has been less need for alignment in the vertical but present fighter aircraft and future strike aircraft require accurate vertical alignment for the measurement of elevation angles, vertical acceleration, and accurate radar ranging.

3.4 Alignment Requirements for Civil/Military Transport Aircraft

The accuracy requirements for route-flying aircraft are less stringent than for offensive aircraft (except in Terminal Areas where accurate fixing aids are available). Since it may be assumed that the rate of fixing position will be practically constant the alignment accuracy required will be a function of speed. If position is required to be maintained within, say, 5 nautical miles of track and the fixing rate is once every half hour then the combined error of heading and drift should not exceed an angle the tangent of which is 5 miles divided by the distance covered in 30 mins. Therefore the misalignment of compass (or platform) and doppler should not have a r.s.s. which is significant compared with the overall track error. A table showing typical values for various cruising speeds is given in Table 1 below:-

Cruising Speed	Acceptable Track Error	Suggested r.s.s. of Heading and Drift Misalignment	Acceptable Misalignment of each Equipment
520 kts. (Boeing 707)	66 arc mins (1.1°)	22 mins	16 mins
Mach 2	30 arc mins ($.5^{\circ}$)	10 mins	7 mins
Mach 3	20 arc mins ($.33^{\circ}$)	7 mins	5 mins

Table 1 - Alignment Requirements for High Speed Transport Aircraft

It will be seen from the above table that for supersonic transport aircraft at speeds of Mach 2 to 3 (e.g. the Concord) equipments will need to be aligned to about 6 arc minutes, a target that is being used for the alignment of equipments on the present generation of military aircraft.

3.5 The Alignment of Inertial Platforms with Associated Equipments

Provided that an inertial platform is initially aligned with respect to terrestrial axes there is no need for its alignment with the aircraft datum. If doppler, search radar or astro information is to be fed to the platform computer, however, these equipments and the platform must be aligned to a common datum; the aircraft datum is the usual, though not an essential, choice.

The accuracy with which these equipments are aligned depends on the C.E.F. required. Given a 5 mile C.F.F. over 2,500 miles and a 500 yards radar fixing requirement the radar must be aligned to about 3° and, assuming simple

/doppler ...

doppler/inertial mixing (or no accurate fixing source is available), the platform/doppler alignment should be better than 2 arc minutes.

3.6 Specification of Alignment Requirements

Alignment requirements, in common with many other weapon studies, are based upon the C.E.F. required and accuracy figures are stated at various probability levels. When an alignment requirements is stated formally in a specification a pass or fail figure must be given. The quandary is to decide which level to use. It is probably best to specify the 1σ level as a pass/fail limit. This seems to be the only way, although an expensive one, of ensuring that at least 68% of the sample are better than the 1σ required, the 2σ or 3σ levels being usable only if one can guarantee a Normal Distribution of errors with a fixed percentage of rejects.

4. Methods of Alignment and Determining Misalignment

The most common method of aligning equipments and projectiles in current service use is by jiggling. This is satisfactory for units mounted within the main section of an aircraft fuselage but the further the unit is mounted away from the aircraft's main datum the more questionable this technique becomes. At best jiggling can probably be relied upon for alignments to within 3-6 minutes of arc but it would depend on the aircraft in question. Even if jiggling may be relied upon for initial installation it is felt that provision should be made for checking the alignment of units from time to time. The question then arises of how alignment should be checked in service.

4.1 Methods of Checking Alignment

Methods of checking alignment can be divided into three main classes:-

(a) Physical Measurement

The most straightforward method of checking the alignment of units, with respect to the aircraft centre-line or one to another, is to take measurements between supposedly parallel axes at right angles to them as illustrated in figure 1. A jig or set of jigs is the most common way of using this method. Jigs are satisfactory for units grouped closely about the aircraft datum but would be cumbersome and inaccurate for units widely spaced. An additional problem posed is the provision of a means of checking the jigs themselves, since they are seldom treated with adequate respect.

(b) Mechanical Methods

A datum gyro (or a compass) may be used to determine the relative or true bearings of the main axes of each item of equipment. The difference in bearing between equipments gives their relative misalignment. The use of a compass would be somewhat restricted by change of deviation within the aircraft and by local anomalies of variation (a magnetically "clean" compass base has constant variation to better than 6 arc minutes, but "clean" compass bases are a rarity at civil airfields). The determination of vertical alignment using magnetic means would be inaccurate.

(c) Optical/Radio Methods

Autocollimation can be used in certain cases to align equipments to each other or to a common alignment datum. Alternatively, a theodolite (or if money is no object, a radio theodolite) may be used to determine the relative, or true, bearing of the main axes of each equipment and a comparison of the bearings will show their misalignment

/one to ...

one to another. An optical method can be made quite simple and quick to use if each equipment has a datum reflecting surface mounted on it, although care must be taken, when directional asexuals are used, to ensure that reflectors are truly aligned with asexual radiation patterns. The axes of each equipment would thus be established in azimuth and in the vertical, although a levelled aircraft standing on a level base would be necessary for the checking of vertical alignment by theodolite.

The use of a theodolite to measure the relative bearing of each equipment from a distant object has already been recommended by A. & A.E.E. for determining the misalignment of equipments situated remote from the aircraft centre-line. Figure 2 illustrates this technique which is fairly accurate in azimuth, but is difficult to use for determining vertical misalignment.

4.2 Future Trends in Alignment Equipment

To determine equipment alignment accurately in two planes, azimuth and the vertical, it is felt that the fastest and most practicable method currently available is a transfer gyro or platform. The transfer platform can give quick readings in elevation and azimuth and can be made as accurate as the aircraft platform. It may also be used, of course, for initial alignment of the aircraft platform at the same time. A. & A.E.E. are at present investigating the possibility of developing a transfer platform capable of aligning aircraft platforms with respect to earth axes and also capable of determining the misalignment between several equipments mounted on an aircraft or missile. It is envisaged that this equipment would comprise a high quality gyro (with three axes of freedom) complete with self contained power supplies. Each equipment, and the aircraft itself, would have a pair of polished stainless steel flats at right angles to each other. A pair of mating surfaces would be mounted on the gyro unit which could then be offered up to each equipment in turn. Alternatively a single reflecting surface on the inner gymbal of a platform could be used in an autocollimation system using a telescope rigidly mounted on the transfer platform. Since a single mirror can show movement about three orthogonal axes, not only could this become a very quick system but it is ideal for determining the misalignment of inaccessible units.

To use the transfer platform to determine the misalignment between several items of equipment the platform should be aligned initially to the main aircraft axes. It should then be offered up to each missile, or piece of navigation equipment, in turn, so that the misalignment of each equipment can be determined. Since the platform was initially aligned to the aircraft, the misalignment will have been measured in aircraft pitch, roll and yaw axes. This misalignment can then be removed by rotating the equipment, with respect to its mounting, by the appropriate amount. Alternatively a note of the misalignment can be made within the aircraft computers.

For the transfer platform to be used to determine the misalignment between equipments on a naval aircraft on a carrier, the method is basically similar to that used on land. It will be necessary, however, to provide indications of change of aircraft pitch, roll and yaw caused by ship's motion between the instant the transfer platform is aligned to the aircraft and the instant that each equipment is monitored. These outputs could be obtained simply and accurately from the aircraft or transfer platform and with some difficulty with S.I.N.S. A schematic diagram of the use of the transfer platform at sea is shown at Figure 3.

The transfer gyro or platform proposed for checking the alignment of sub-systems can also be used, of course, for the pre-flight alignment of aircraft platforms. To do this on land the transfer equipment would first be aligned with respect to earth axes. This can be done using a surveyed datum (on a permanent airfield) or by internal gyro-compassing (permanent or temporary

/airfields) ...

airfields). Having aligned the transfer platform, it can be taken to several aircraft in turn (see Figure 4.) and the aircraft platforms can each be aligned to it either by synchro matching or velocity matching techniques. Since the transfer can take place at any point on an airfield there would be no necessity for an aircraft to be taken to a particular part of an airfield for pre-flight alignment. The transfer of information being a rapid process (1 minute or so) there would be little interference with operations. At sea the pre-flight alignment is just as simple as on land. The datum to which the transfer equipment is aligned, however, is more difficult to provide. The transfer platform can be aligned to each axis by astro (if position and time are accurately known), by gyro compassing if inputs of ship's rate are available or by alignment to the ship's platform if accurate enough. (Pre-flight alignment at sea is also illustrated in Figure 3).

4.3 Some Problems Associated with Alignment Methods

Some of the problems associated with alignment in general and the disadvantages of the various methods suggested above are:-

(a) Accessibility

Some equipments on which the alignment should be checked are very inaccessible although the autocollimation/transfer gyro method should overcome this.

(b) Alignment Afloat

The space available for servicing, particularly hangar space, is severely limited on an aircraft carrier thus precluding the use of large jigs. The instability of the carrier would make the use of a transfer gyro method more difficult but certainly not impossible. For units situated close together autocollimation may well be the best solution.

(c) Equipment Servicing

It is felt that whenever a unit requiring accurate alignment is removed during servicing the alignment should be subsequently checked. It is a requirement for some service and civil aircraft that equipments should not require alignment after replacement, all similar units being interchangeable, but this is felt to be rather optimistic, where stringent alignment tolerances are laid down.

(d) Limitations of Jigs

Apart from the limiting accuracy of jigs stated above, they are thought to be too slow and cumbersome. Neither do jigs and sighting rods receive the respect they deserve in service.

(e) Limitation of the Theodolite Relative Bearing Method

The relative bearing method outlined earlier is not really suitable for aligning equipments in three axes although it is a quick and reliable method of determining misalignment in azimuth.

(f) Limitations of a Datum Magnetic Compass

A datum magnetic compass would be limited to something worse than 0.1° and could only be used in "clean" magnetic environments which would exclude many aircraft currently in service.

4.4 Recommended Alignment Methods for Current and Future Aircraft

For current military aircraft and equipments requiring moderately

/accurate ...

accurate alignment (6 arc minutes or more) jiggling and checking by jig is recommended if the equipments are suitably situated. Where the use of a jig for checking alignment is unsuitable, optical methods (autocollimation or theodolite) are recommended. For aircraft using inertial platforms requiring datum alignment the use of a transfer platform for this and checking the alignment of other equipments is recommended. The problem of stability and space on board ship might limit alignment checks to periods when the carrier is in harbour unless the transfer platform method is used.

Current civil aircraft systems can tolerate an alignment error of $\frac{1}{2}^{\circ}$ or worse and it is therefore considered adequate to rely on manufacturers' jiggling. In future aircraft, however, where inertial systems are used it is felt that (as Table 1 shows) improved methods of alignment will be required. Optical methods will probably be more attractive to the financial resources of airline operators. A theodolite could be used quite easily to determine misalignment between equipments and could conceivably be used for datum alignment of the platform. This would be a slow process, however, requiring accurate positioning of the aircraft. If speed and flexibility are required the use of a transfer gyro will probably be the only answer.

4.5 Alignment Datum

For most aircraft the alignment datum used is the geometric centre-line as laid down during aircraft manufacture. This datum is assumed to coincide with the flight centre-line although few aircraft manufacturers will guarantee this. For some aircraft the main cross-sectional member of the nose section (which bears the main radar) is used as the main datum and all sub-systems are related to this. For line of sight aiming this is satisfactory but it is argued that for computed manoeuvres, like L.A.B.S., account must be taken of the difference between the geometric centre-line and the flight centre-line including the effects on this of changes at all up weight, speed and attitude during flight. It is suggested that for future aircraft navigation and weapon systems the most logical datum would be either the aircraft inertial platform which would effectively align equipments to the ground velocity vector or, if applicable, the datum of the missile carried which would represent aligning all information sources to the point of ultimate use.

5. Further Sources of Error in Navigation Systems

Apart from the basic misalignment problem and the inherent errors of the equipments comprising a navigation system, there are further sources of error between the basic input and the final data which is fed to the computing element of the system. Some of these are discussed in the following paragraphs.

5.1 Aircraft Behaviour

An aircraft is normally regarded as a structure that maintains its shape during flight and, as mentioned earlier in this paper, one that flies along its geometric centre-line. These assumptions in themselves give two sources of error:-

(a) Aircraft Flexure

In flight, aircraft flex in all three axes and do not always return to precisely their basic shape. To minimise this effect all navigation equipment sensors (e.g. radar aerials, dopplers, astro-trackers, visual sights and inertial platforms) should be grouped together, preferably at the Centre of Gravity.

(b) Heavy Landings

The strains applied to an aircraft structure during catapulted take-offs and deck landings, on carriers, and heavy landings on

/firm ...

firm ground may well cause an accurate alignment to be degraded.

The magnitude of these two effects can be expected to vary in proportion with the distance between aligned equipments.

5.2 Transmission Problems

The accuracy with which data is transmitted from source to user is affected by:-

- (a) Synchromotor accuracy.
- (b) Power supply quality.

5.3 Mounting Rigidity

Since many equipments are on anti-vibration mounts it is necessary that these mounts be free of lateral play in order that equipments are only free to move in one plane, so that movement is parallel to the aircraft's main axes without tilting or slewing.

5.4 Corrections for Aircraft Behaviour and Transmission Errors

Since errors caused by aircraft flexure, power supply fluctuations and synchro errors cannot be eliminated, but can be measured, it is necessary that account of these effects be taken within navigation and weapon computers.

6. Conclusions

It is suggested that a two part approach is necessary to future work on the alignment of equipments. Firstly during the early stages in conception of an aircraft, or weapon system, an overall method of alignment must be formulated, so that all units are aligned by a common method, to a common datum and so that adequate provision is made for the alignment of the sensing element of a unit rather than its case. Secondly it is felt that work should commence as soon as possible on the determination of a standardised alignment technique for use on all future systems. Investigations in this direction have already started within Experimental Navigation Division, A. & A.E.E.

The transfer platform method of alignment outlined in this paper is thought to provide the greatest development potential for the initial alignment of platforms, the alignment of equipments to a common datum and the correction of bias errors in synchro transmission loops.

It is hoped that a development programme will soon be started to examine the qualities and capabilities of transfer gyros/platforms in isolation, and in association with autocollimation methods, with a view to developing a standardised technique and equipment for the alignment of sub-systems. Only in this way can the existing multiplicity of alignment methods, jigs and other devices be reduced.

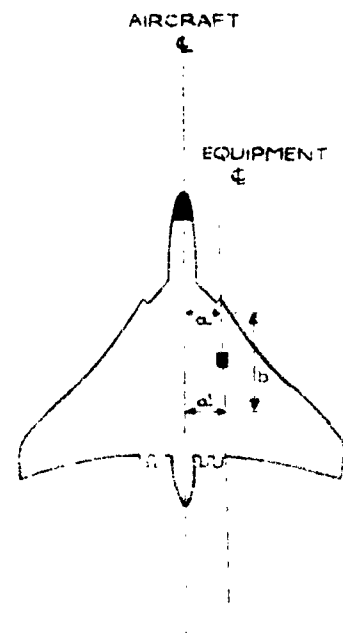
References

<u>No.</u>	<u>Title</u>
1	General Alignment Problems, September 1962. Dr. G. E. Roberts, R.A.E.
2	An Examination of the Optical Arrangement for Aircraft Sighting Rods (ANR/25/010), March 1962. Flight Lieutenant E. S. Williams, A. & A.E.E.
3	Alignment of the Doppler Datum to the Heading Datum in Military Transport Aircraft (ANR/22/02), October 1962. Squadron Leader E. T. Wood, A. & A.E.E.
4	Alignment of Vulcan B Mk.2 Bombing and Navigation Sub-Systems for the Skybolt Role (ANR/67/06). Squadron Leader P. H. R. Clifford, A. & A.E.E.

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$$\text{MISALIGNMENT } \angle = \tan^{-1} \left(\frac{a' - a}{b} \right)$$

**FIG. 1. DETERMINATION OF MISALIGNMENT BY
LINEAR MEASUREMENT**

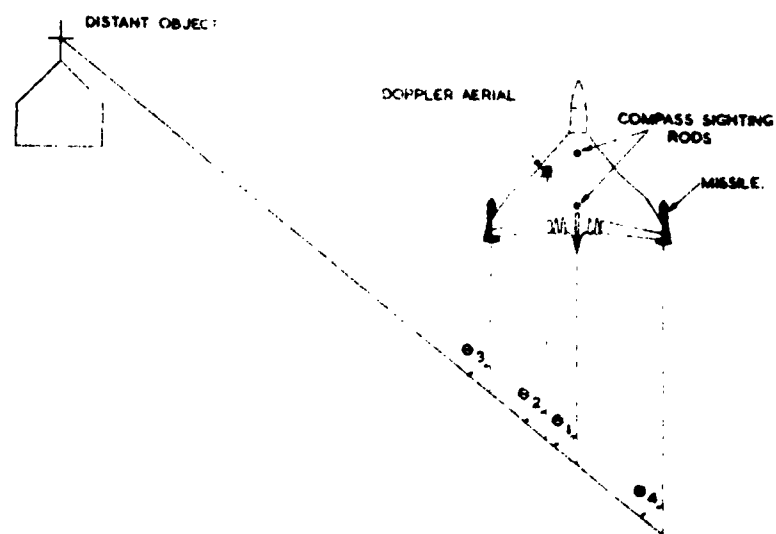


FIG. 2. ALIGNMENT USING A THEODOLITE.

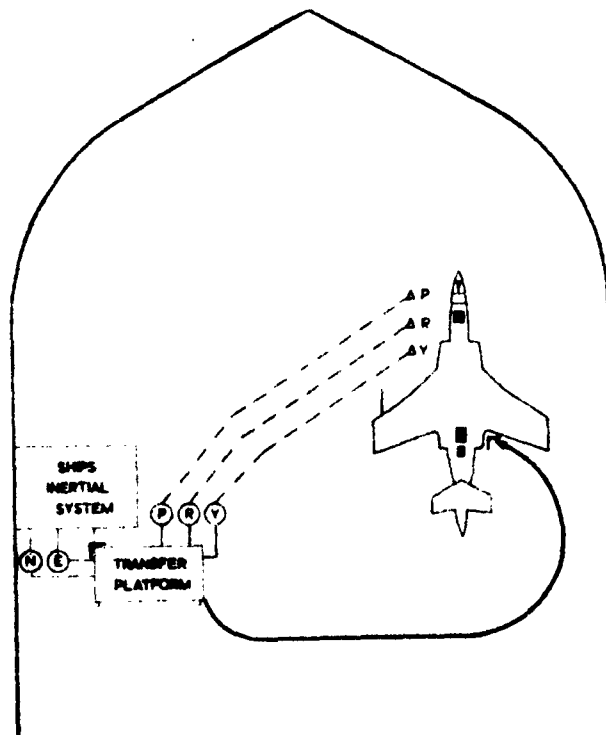


FIG. 3. ALIGNMENT AT SEA.

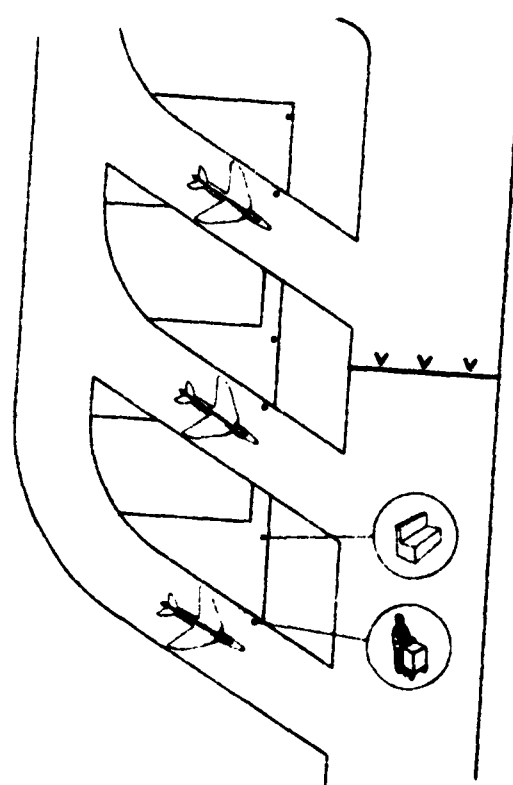


FIG. 4. ALIGNMENT ON A PERMANENT AIRFIELD.

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